Improved three-dimensional velocity models and earthquake locations for California

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Investigations Undertaken

Our work focuses on the development of a three-dimensional (3-D) seismic wavespeed model for the greater San Francisco (SF) Bay Area, in preparation for the centennial of the great 1906 San Francisco earthquake. The model will be used by others to compute strong ground motions in a simulation of the 1906 event and it will help to characterize both well-known and hidden seismogenic structures. The dataset combines P-wave arrival times from a well-distributed set of about 7,000 earthquakes with a complete archive of available active-source (explosion) P-wave travel times from the region. The wavespeed modeling is being carried out with a combination of conventional and "double-difference" seismic tomography.

Results

We have been working in collaboration with Tom Brocher of the USGS to assemble an active-source dataset that is as complete as possible for the northern California region, including some data that have never been utilized previously for seismic tomography. We have also extracted catalog phase arrivals for some of the larger shots recorded at the NCSN stations. That effort is essentially complete, including cross-checking of source and receiver coordinates and receiver-name rationalization across all experiments (plus the NCSN). A map showing all the available active-source lines is presented in Figure 1.

In parallel, we have extracted arrival-time data for about 7000 earthquakes that are optimally distributed throughout the current study region. We have compiled and merged all of these data and carried out a preliminary "conventional" tomography analysis using simul2000 [Thurber and Eberhart-Phillips, 1999], to be followed by double-difference (DD) tomography [Zhang and Thurber, 2003]. Preliminary inversion results for our original, slightly smaller study region, using about 6,000 earthquakes (Figure 2) and 5,500 shots/airgun blasts, are presented here. Work on an expanded region is in progress and will be presented at the Fall AGU meeting.

The current model grid for the inversion uses 10 km spacing in the horizontal directions and gradually increasing grid intervals, from 1 to 5 km, in the vertical direction. We use a one-

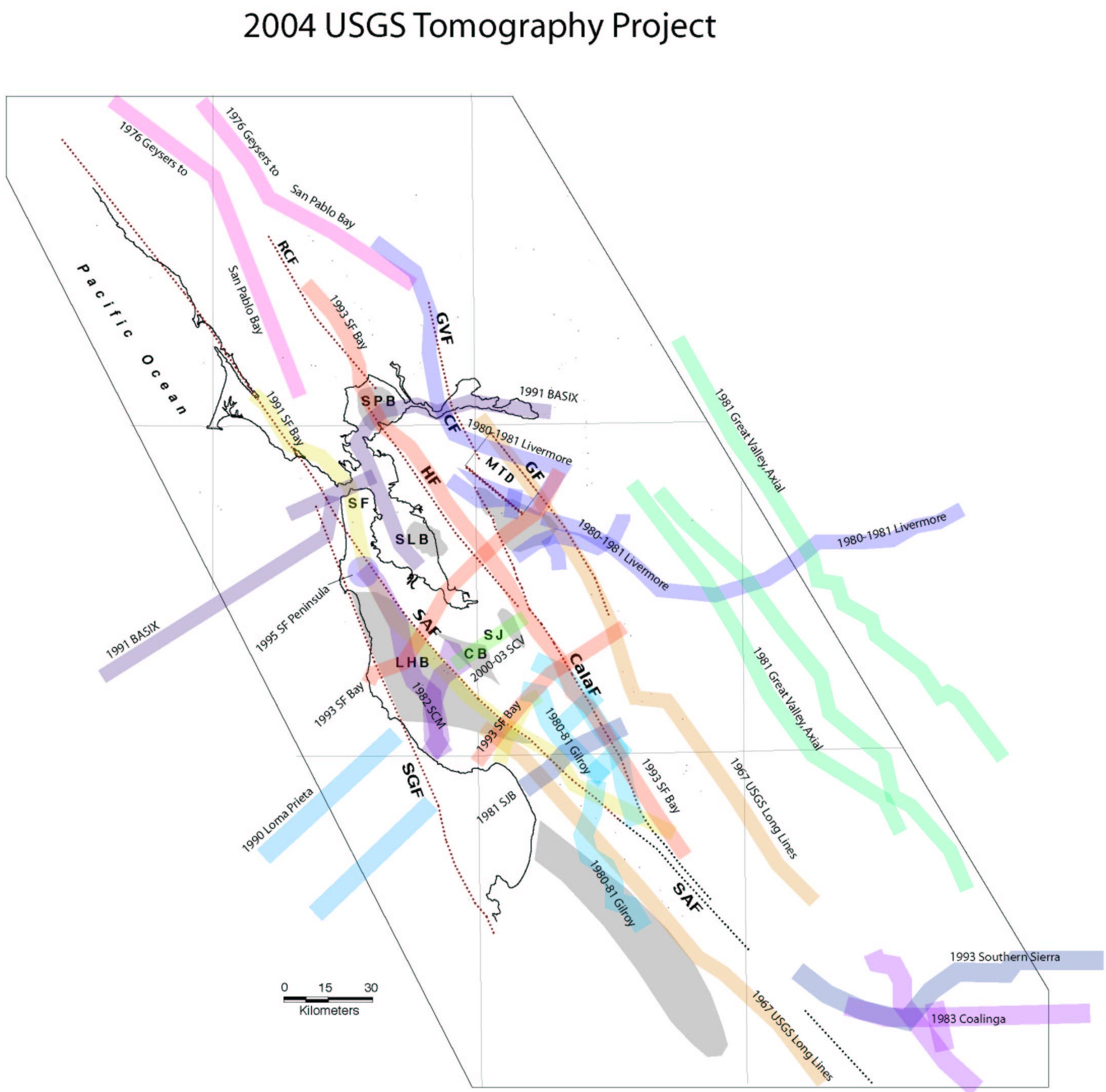

Figure 1. Map of active-source (explosion and air-gun) surveys compiled by Tom Brocher and provided to this project. Integration and reformatting of these data have been carried out.

dimensional model from Hole et al. [2000] as our starting model. The inversion achieves an 80% variance reduction, bringing the final RMS residual to 0.15 s.

The preliminary model covers the region west of the Great Valley from Hollister to Clear Lake. The geometries of the major faults are clearly defined by the relocated seismicity, and most of the seismogenic faults are marked by significant wavespeed features. Where the models overlap, our results are quite similar to those of Thurber [1983], Dorbath et al. [1996], and Eberhart-Phillips et al [1998], among others, although in general our resolution of structure appears to be

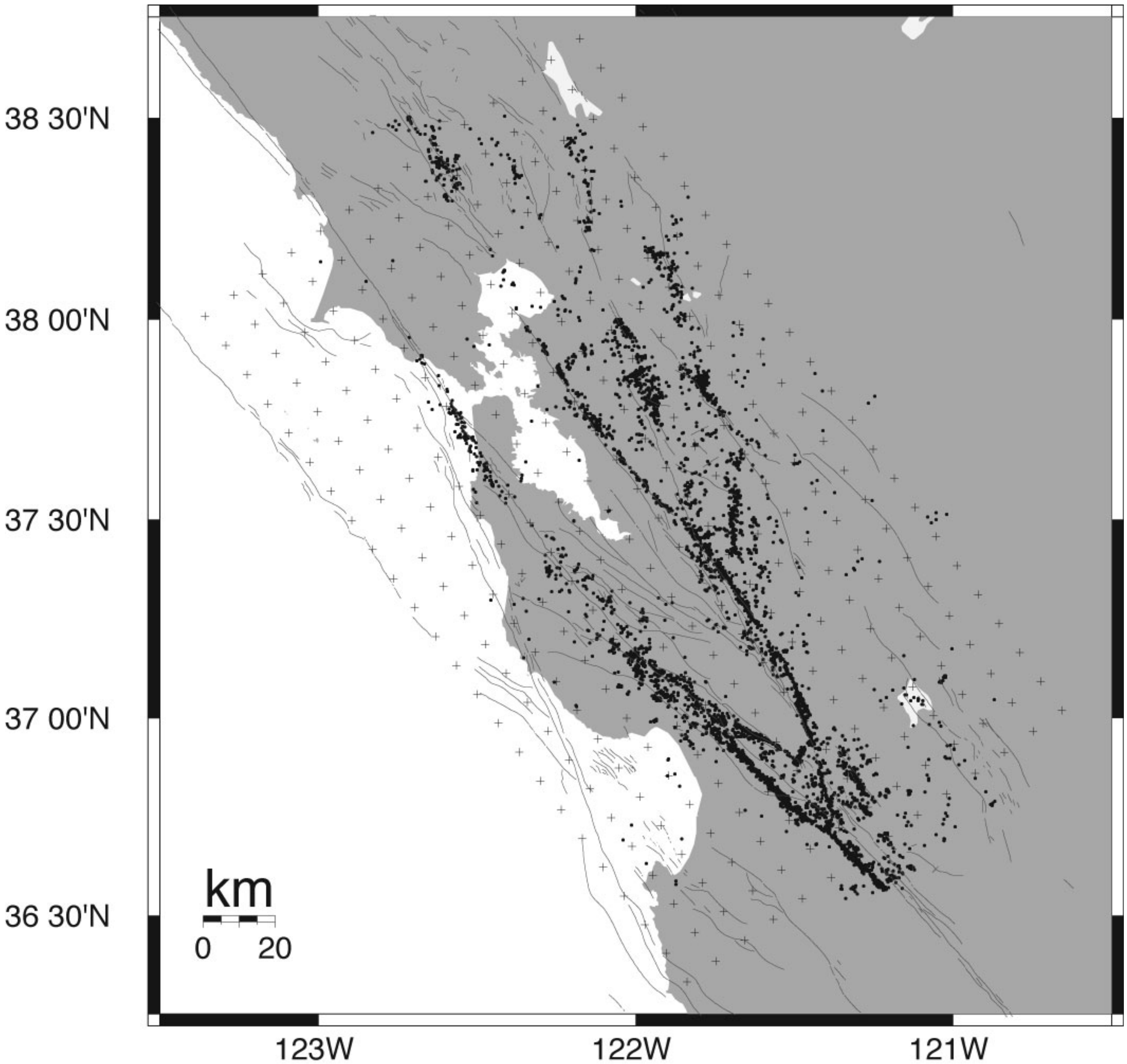

Figure 2. Map of the earthquakes (circles) and layout of the inversion grid (crosses) for our preliminary inversion. Node spacing is 10 km in the horizontal directions, and grades from 1 km at the surface to 5 km at 15-20 km depth. Faults are shown as thin lines.

significantly improved. We attribute the improvement to the size of the dataset and the abundance of active-source data.

Seismically active strike-slip faults with reasonable surface exposures predominate in the region, but we are especially interested in faults or fault segments that are more challenging to characterize. Basement structures identifiable in gravity and magnetic data and in the wavespeed model appear to control the seismicity associated with the Ortigalita fault (which runs through San Luis Reservoir), an unmapped strike-slip fault connecting the Calaveras and Greenville faults, and an apparent thrust fault on the edge of the Great Valley near Vacaville. Figure 3

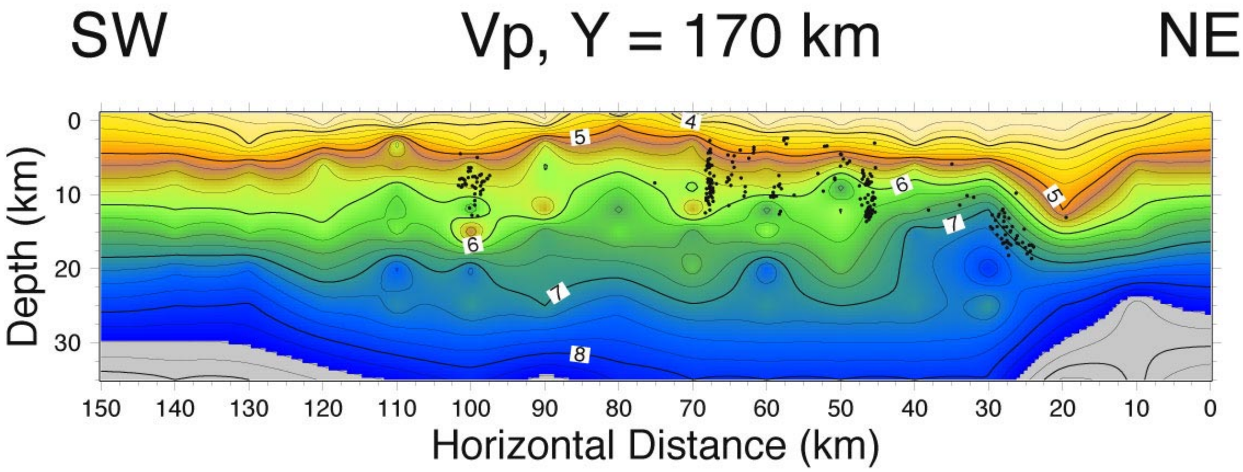

Figure 3. Cross-section through the P-wavespeed model along a profile crossing through San Francisco and Vacaville. Countour interval for the P wavespeeds is 0.25 km/s. Earthquake hypocenters within 5 km of the section are indicated by circles.

shows an example cross-section through our 3-D model crossing through San Francisco and Vacaville. The main faults apparent in the seismicity, from southwest to northeast, are the San Andreas (km 100), Hayward (km 68), and Vacaville-Kirby Hills (km 47). We also note the seismically active ramp-like structure between km 30-20 that apparently is a reverse fault near the edge of the Great Valley.

References

Dorbath, C., D.H. Oppenheimer, F. Amelung, and G.C.P. King, Seismic tomography and deformation modeling of the junction of the San Andreas and Calaveras faults, *J. Geophys. Res*. *101*, 27,917. 1996.

Eberhart-Phillips, D., and A.J. Michael, Seismotectonics of the Loma Prieta, California, region determined from three-dimensional Vp, Vp/Vs, and seismicity, *J. Geophys. Res*. *103*, 21,099, 1998.

Hole, J. A., T.M. Brocher, S.L. Klemperer, T. Parsons, H.M. Benz, and K.P. Furlong, Three-dimensional seismic velocity structure of the San Francisco Bay area, *J. Geophys. Res. 105*, 13,859, 2000.

Thurber, C.H., Earthquake locations and three-dimensional crustal structure in the Coyote Lake area, central California, *J. Geophys. Res.*, *88*, 8226, 1983.

Thurber, C., and D. Eberhart-Phillips, Local earthquake tomography with flexible gridding, *Comp. & Geosci.*, *25*, 809, 1999.

Zhang, H., and C.H. Thurber, Double-difference tomography: method and application to the Hayward fault, California, *Bull. Seismol. Soc. Am.*, *93* 1875, 2003.

Reports Published

Thurber, C., H. Zhang, V. Langenheim, and T. Brocher, Geophysical characterization of seismogenic structures in northern California, Eos Trans. AGU, 85(47), Fall Meet. Suppl., Abstract S51D-01, 2004.